

Precision Signal Power Measurement Equipment—Radio Frequency Section

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The Precision Signal Power Measurement (PSPM) equipment has been installed at the Goldstone Mars Station, DSS 14. The PSPM equipment features a highly flexible radio frequency (RF) section providing amplification, frequency translation, filtering, sampling and analog to digital (A-D) conversion of the 50 MHz Block III Receiver or 55 MHz Block IV Receiver intermediate frequency (IF) signals. Remote control of gain, tuning and filter selection permits hands-off operation of the RF section of the equipment. This article describes the RF section of the PSPM equipment.

I. Introduction

The Precision Signal Power Measurement (PSPM) equipment has been installed in the Mars Station (DSS 14) at Goldstone. An integral part of the PSPM hardware is a radio frequency (RF) section which translates a narrow slice of the receiver's 50 MHz (Block III) or 55 MHz (Block IV) intermediate frequency (IF) spectrum to baseband. Sampling and A-D conversion of the baseband signal are also provided in the RF section. The baseband data are then submitted to the digital section of the PSPM system for spectral analysis and signal-to-noise ratio (SNR) formulation. A second channel in the RF section measures the total IF bandwidth power. This channel consists of a broadband square law detector (Ref. 1) and an A-D converter, and is used with a calibrated noise adding diode to accurately and continuously measure system tempera-

ture. This article describes the RF section of the PSPM equipment. The balance of the PSPM equipment and its operation are described in Reference 2.

II. RF Section Requirements

The PSPM equipment is designed to operate over a wide dynamic range of signal level conditions, processing the IF signals from either Block III or Block IV receivers, while simultaneously measuring system temperature. The RF section satisfies the following requirements:

- (1) It is tunable to the 50 MHz IF of the Block III receiver or to the 55 MHz IF of the Block IV receiver.
- (2) It provides a tuning range of ± 1 MHz about either of these IFs to permit precise power level measure-

ments of individual sideband components of the signal.

- (3) It provides three selectable sampling bandwidths and filters for extended strong signal measurement capability.
- (4) Its RF attenuators, 50/55 MHz preselector tuning and baseband filter selection are remotely controlled by the PSPM MAC-16 computer.
- (5) It provides signal level monitors at key points in the RF chain to alert system users to improper operation, loss of signal or equipment malfunction.
- (6) It provides a noise adding radiometer (NAR) channel which measures the total IF bandwidth power.
- (7) It provides 12-bit A-D conversion for signal and NAR channels.

III. System Description

Figure 1 is a simplified block diagram of the PSPM RF section showing its connections to the DSN receivers. The IF signals from Receivers 1 through 4 are buffered by a set of R&D isolation amplifiers and are then supplied to the PSPM equipment. Within the PSPM RF section, the selected receiver's signal is split and simultaneously applied to the signal channel and NAR channel inputs. Signal data and noise data are supplied to the PSPM digital section.

A detailed block diagram of the PSPM RF section is shown in Figure 2. The signal channel consists of four modules, while the NAR channel uses only one module plus the broad band square law detector.

A. Power Splitter Module

The power splitter module is the first module in the signal channel. This module amplifies the 50 MHz or 55 MHz IF signal of the selected receiver, provides four isolated output ports, and exhibits a maximum gain of 34 dB. The gain of this module is controllable over a 31.5 dB range, in increments of 0.5 dB. The programmable attenuator providing the gain control is driven by a set of six optocouplers.

B. Tunable IF Module

The function of the tunable IF module is to translate the 50 MHz or 55 MHz IF signal to 10 MHz (less a small offset frequency), bandpass filter the 10 MHz signal, and provide controllable gain.

The tunable IF module receives its input from the power splitter module. The signal is bandpass filtered, amplified and fed to the input of the PSPM first mixer. The voltage-tuned bandpass filter prevents noise folding in the first mixer by providing approximately 30 dB of attenuation at the image frequency (20 MHz below the input frequency). One digital control line, optocoupled to a precision voltage generator, tunes the filter to 50 MHz or 55 MHz. Local oscillator (LO) drive for the first mixer is provided by a saturated amplifier driven by a Hewlett Packard frequency synthesizer. Since this RF system employs a fixed frequency (10 MHz) LO for the second mixer, the frequency offsets must be computed and entered in the first LO. The correct LO frequency is determined by first subtracting 10 MHz from the incoming frequency and then adding an offset frequency whose value is equal to one half of the corner frequency of the baseband module's selected low pass filter. For example, consider a carrier power measurement of a signal supplied to the PSPM equipment by a Block III receiver. For this example, assume that the 25 Hz low-pass filter has been selected. The carrier supplied to the PSPM equipment will be at precisely 50 MHz, locked there by the Block III receiver's RF loop. The LO frequency of the PSPM equipment must be:

$$50 \text{ MHz} - 10 \text{ MHz} + (25 \text{ Hz})/2 = 40,000,012.5 \text{ Hz}$$

This LO frequency will yield a baseband module output with the received signal exactly centered in its 25 Hz power spectrum.

After being translated to the 10 MHz IF by the PSPM first mixer, the signal is narrow band filtered, amplified and passed through a programmable attenuator. This attenuator adjusts the gain of the tunable IF module from -0.5 dB to +30 dB.

C. Baseband Module

The 10 MHz IF signal supplied to the baseband module is amplified and fed to a two-way power splitter. One output of the power splitter leads to the baseband mixer, while the other drives a power level detector. A meter connected to the detector output yields a continuous indication of the 10 MHz IF power level. The second mixer translates the 10 MHz IF signal to baseband. A 5 MHz frequency doubler and saturated amplifier supplies LO drive to the baseband mixer. Following the baseband mixer is a low-noise 26 dB gain amplifier which drives the three low-pass filters. These active low-pass filters were designed to exhibit 6-pole Chebyshev response with pass-band ripple of 0.1 dB. Corner frequencies of 22 Hz, 220 Hz and 2.2 kHz were chosen to prevent frequency aliasing

when using sampling bandwidths of 25 Hz, 250 Hz and 2.5 kHz, respectively. In-band power gain of each filter is inversely proportional to its bandwidth, making the output noise power independent of which sampling bandwidth and low-pass filter is selected. A set of remotely controlled relays couple the baseband signal through the output buffer and direct-current blocking capacitor to the module output. Since the three low-pass filters have different gains, module gain is a function of filter selection. The baseband module's gain is 71.6 dB with the 25 Hz filter, 61.6 dB with the 250 Hz filter, and 51.6 dB with the 2.5 kHz low-pass filter. The output level capability of this module is compatible with the ± 10 -volt input range of the signal A-D converter module.

D. Signal and Noise A-D Converter Modules

The signal and noise A-D converter modules are very similar in design. Both modules use modular sample and hold amplifiers and 12-bit A-D converters. Differentially arranged transistor-transistor logic (TTL) drivers buffer the data and status lines, driving optocoupled receivers in the digital section of the PSPM equipment. Sampling pulses generated within the digital section are received by optocouplers in the two A-D modules. The sampling rate in the NAR channel is 500 samples/second. In the signal channel, Nyquist sampling rates of 50 Hz, 500 Hz and 5 kHz are used with their respective 25 Hz, 250 Hz and 2.5 kHz low-pass filters. The signal A-D converter is wired to accept input voltages of ± 10 volts peak, with negative values coded in two's complement. The noise A-D converter is wired for unipolar operation, receiving its 0- to +10-volt input from the broadband square law detector. Contained within the signal A-D converter module is a peak-reading meter circuit. A meter connected to this detector allows the equipment operator to monitor the signal level at the input of the signal A-D converter.

IV. Packaging

The PSPM technique of signal power measurement is based on the comparison of signal and noise powers in known bandwidths. To make accurate signal power measurements of weak signals it is essential to preserve the power spectrum of the received signal, and not corrupt the power spectrum by allowing stray RF leakage

into the signal channel. Carrier power measurements are susceptible to RF leakage because the signal frequency is either 50 MHz or 55 MHz and is therefore harmonically related to most standard frequencies and timing signals distributed throughout the tracking station. Signal contaminants, along with the received signal, are amplified by the PSPM equipment's high gain which, at maximum, is approximately 136 dB.

The RF hardware is packaged in five modules which provide adequate isolation and shielding. Internal cavities are machined into the modules to accommodate individual circuit boards and RF components. Cover plates are secured on both sides of each module, ensuring an RF-tight enclosure. Three-terminal voltage regulators provide local power supply regulation within each module. Radio frequency decoupling of sensitive components is provided in the power supply lines by using inductance-capacitance (LC) filters as cavity wall feedthroughs. Optocouplers provide RF isolation from control and data lines entering the modules. Input and output signals are passed through coaxial connectors on the module front panels, while control lines, data lines and power supplies connect through multi-pin connectors on the rear of the RF modules. Figures 3 and 4 show the left and right sides of the baseband module with the covers removed. Similar construction techniques were used in the other four modules.

The five RF modules are housed in one rack-mounted cage. Engagement of the module connectors to mating connectors in the cage is automatic when the modules are inserted into the cage and secured in place by tightening two thumbscrews in each module's front panel. Figure 5 shows the RF cage (with the modules inserted) and the square law detector. The coaxial cables which interconnect the modules were removed for this photograph.

V. Summary

The RF section shown in Figure 2 has been constructed and installed as part of the PSPM equipment at the Goldstone Mars Station, DSS 14. The PSPM equipment has been used to simultaneously measure system temperature and carrier power during actual spacecraft tracks, rendering data which were in close agreement with operationally observed values.

References

1. Reid, M. S., Gardner, R. A., and Stelzried, C. T., *A New Broadband Square Law Detector*, Technical Report 32-1599. Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1975.
2. Constenla, L. C., "Precision Signal Power Measurement and Noise-Adding Radiometer System," in this issue.

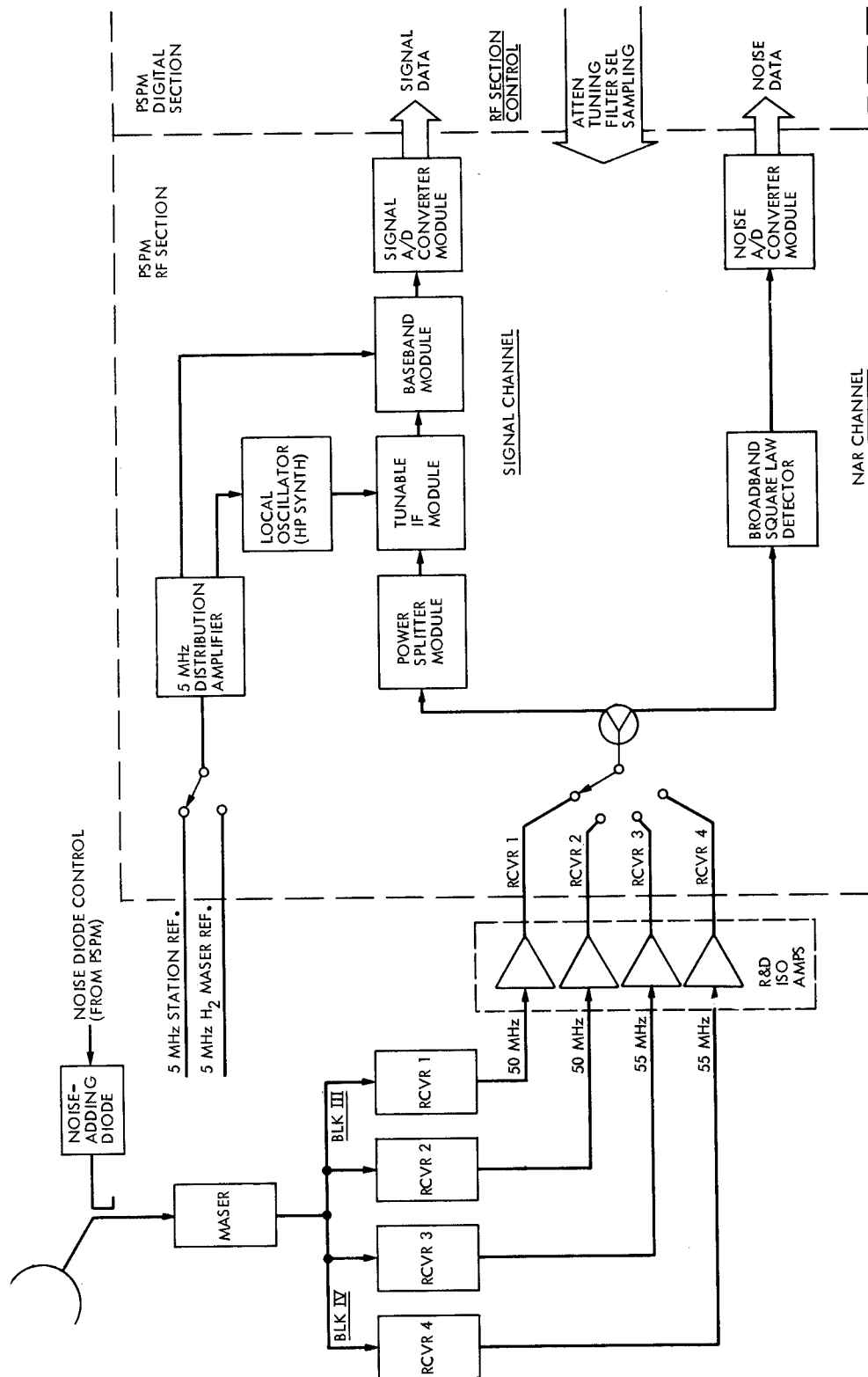


Fig. 1. PSPM equipment RF section, simplified block diagram

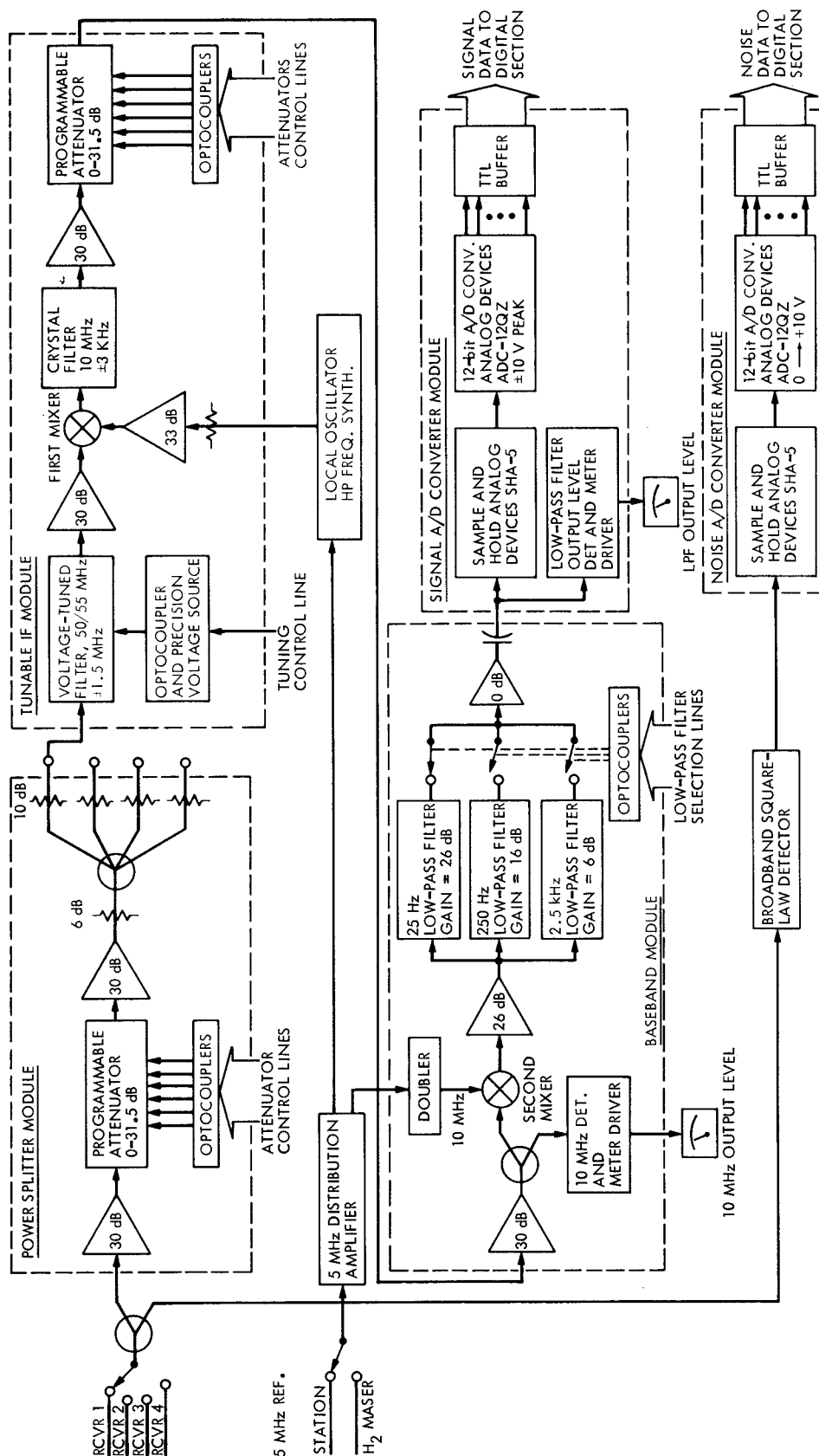


Fig. 2. PSPM equipment RF section, detail block diagram

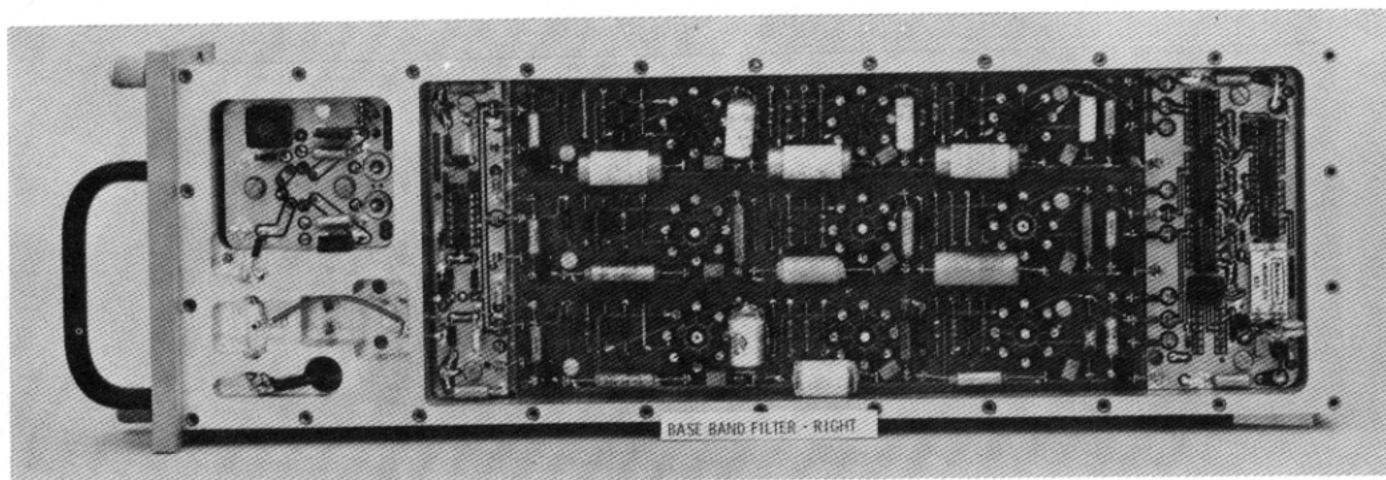


Fig. 3. Baseband module, right side

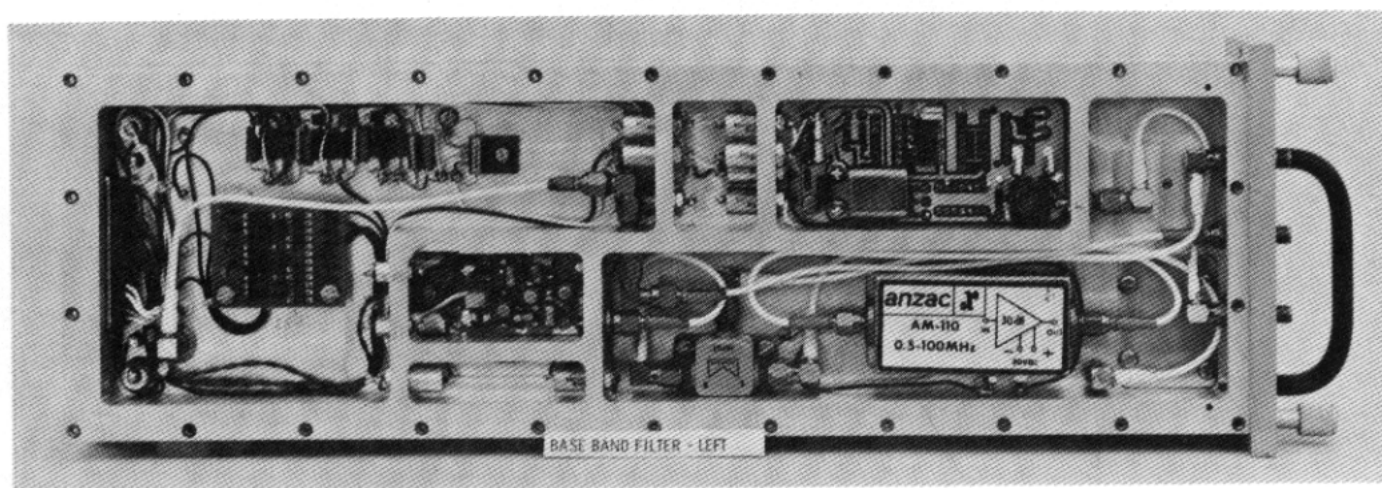


Fig. 4. Baseband module, left side

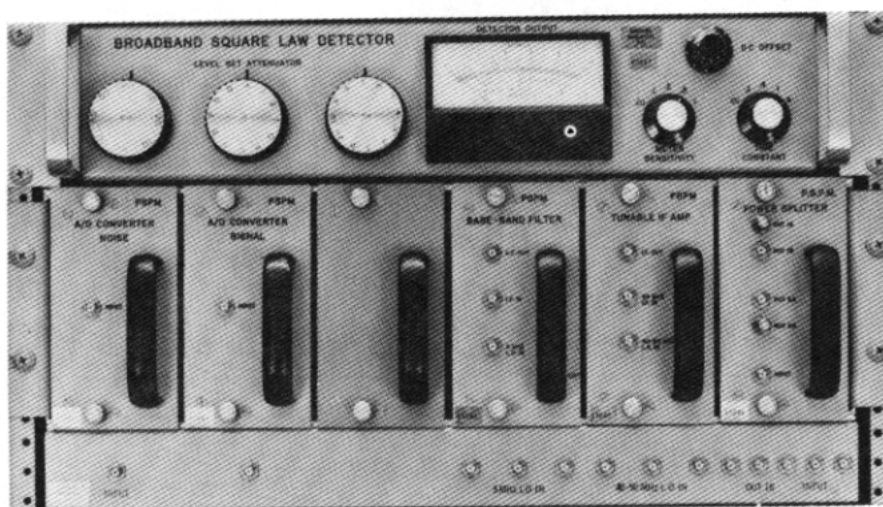


Fig. 5. Broadband square law detector and RF cage